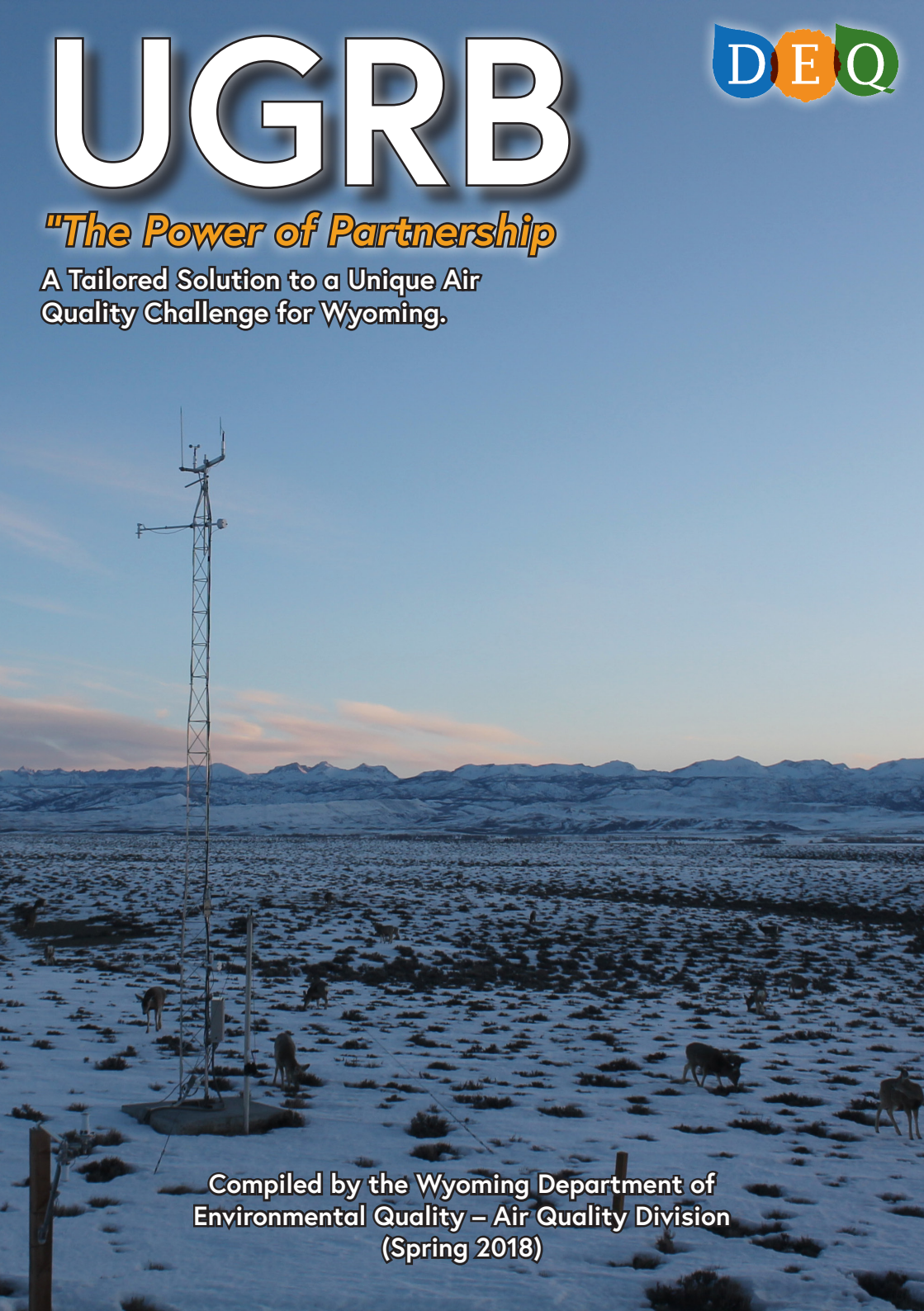
UGRB

"The Power of Partnership

A Tailored Solution to a Unique Air Quality Challenge for Wyoming.



Compiled by the Wyoming Department of Environmental Quality – Air Quality Division
(Spring 2018)

UGRB: THE POWER OF PARTNERSHIP

Compiled by the Wyoming Department of Environmental Quality – Air Quality Division (Spring 2018)

Wyoming Department of Environmental Quality Director Todd Parfitt

Images courtesy of the Wyoming Department of Environmental Quality

For more information, on WDEQ, please visit: www.deq.wyoming.gov/

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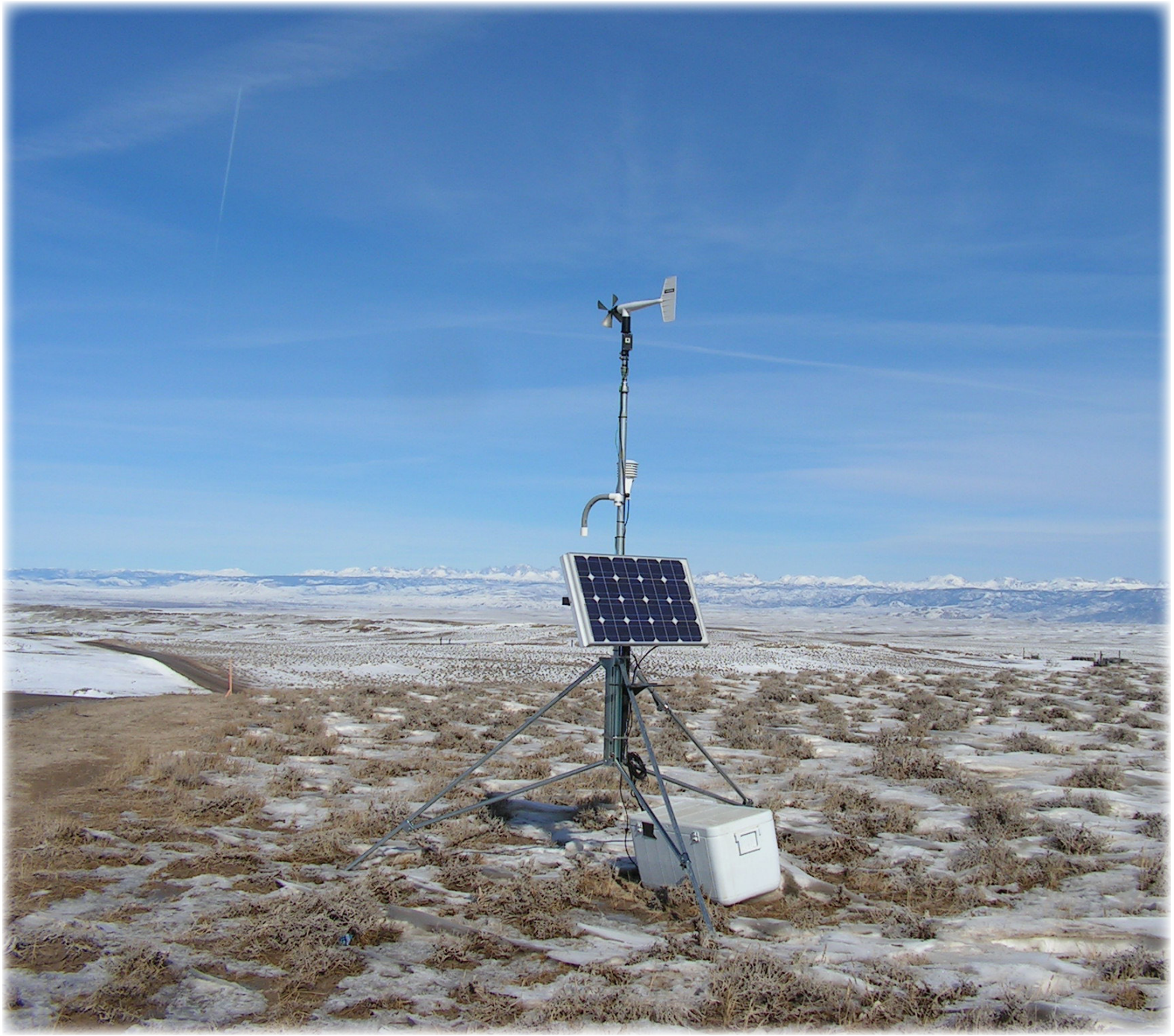

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Produced by the Wyoming Department of Environmental Quality - Air Quality Division

GLOSSARY OF TERMS

A scientific measurement is performed as part of the Upper Green Winter Ozone Study (UGWOS).

The following terms and acronyms appear in this document and are listed alphabetically for reference.

AQD: Air Quality Division
AQRM: Air Quality Resource Management Program
BLM: U.S. Bureau of Land Management
BACT: Best Available Control Technology
CASTNet: Clean Air Status and Trends Network
CDA: Concentrated Development Area
COWD: Commercial Oilfield Waste Disposal Ponds
Division: Wyoming Department of Environmental Quality – Air Quality Division
ECMWF: European Centre for Medium-Range Weather Forecasts
EPA: U.S. Environmental Protection Agency
GFS: Global Forecast System
HAP: Hazardous Air Pollutant
HONO: Nitrous Acid
JPAD: Jonah & Pinedale Anticline Development Area
JPAD/NPL: Jonah & Pinedale Anticline Development Area and Normally Pressured Lance
LAER: Lowest Achievable Emission Rate
LDAR: Leak Detection and Repair
NAA: Nonattainment Area
NAAQS: National Ambient Air Quality Standards
NAM: North American Mesoscale
NEPA: National Environmental Policy Act
NOx: Nitrogen Oxides
NAA: Nonattainment Area
O_3: Ozone
OAD: Ozone Action Day
OCP: Ozone Contingency Plan
PAD: Multiple Well Facility
PAPA: Pinedale Anticline Project Area
P-BACT: Presumptive Best Available Control Technology
PM_{10}: Particulate Matter less than 10 microns in size
ppb: Parts Per Billion
ROD: Record of Decision
SIP: State Implementation Plan
SO_2: Sulfur Dioxide
SPM: Special Purpose Monitor
Task Force: UGRB Air Quality Citizens Advisory Task Force
TPY: Tons Per Year
UGRB: Upper Green River Basin
UGWOS: Upper Green Winter Ozone Study
VOC: Volatile Organic Compound
WAQSR: Wyoming Air Quality Standards and Regulations
WDEQ: Wyoming Department of Environmental Quality
WRF: Weather Research and Forecasting Model

THE POWER OF PARTNERSHIP

The discovery of elevated ozone levels in the Upper Green River Basin (UGRB) in 2005 brought a complex air quality issue to the forefront in the State of Wyoming, requiring the Department of Environmental Quality – Air Quality Division (the Division) and affected stakeholders to undertake a comprehensive analysis of the problem and develop response measures. Upon preliminary study, it quickly became clear that there were no easy pathways to resolving the ozone issue in the UGRB. Instead, the beginnings of a long road of research, pollution control, and collaboration were laid by stakeholders from all perspectives – from industrial proponents, environmental groups, and concerned citizens to state and federal entities. Over 10 years later, that road has helped pave the way to cleaner air in the UGRB.

In the time since the area was designated nonattainment for the 2008 ozone NAAQS in July 2012, the UGRB has attained the 2008 ozone National Ambient Air Quality Standard (NAAQS) primary standard of 75 ppb every year (2012-2017) based on the specified metric of a fourth-highest daily maximum reading. Although the fourth-highest daily maximum reading for 2017 (73 ppb) was above the 2015 ozone NAAQS (70 ppb), the three-year design value for the Boulder monitor from 2015-2017 was 62 ppb, which is in attainment of the 2015 ozone NAAQS. The 73 ppb value at Boulder for 2017 was much lower than the 101 ppb value at the same site for 2011.

A multitude of ozone strategies have been developed and implemented, and numerous regulatory control measures have been adopted into law. Thousands of tons of volatile organic compounds (VOCs) and nitrogen oxides (NO_x) have been offset and reduced. In 2016, the EPA issued a Determination of Attainment for the UGRB – acknowledging that the UGRB had attained the standard for more than three consecutive years and had achieved this attainment by the required date of July 2015. This Determination of Attainment marked an important milestone towards redesignating the area to attainment.

In short, we've made progress by working together. The feedback that the Air Quality Division has received in dozens of stakeholder meetings and public outreach forums has helped inform the development of effective pollution control strategies and mitigation steps on elevated ozone days. There are now numerous operators in the UGRB who implement contingency measures on Ozone Action Days, as forecasted by the Division. The Division continues to work to fulfill remaining Clean Air Act requirements for marginal ozone nonattainment areas, and has made several State Implementation Plan (SIP) submittals applicable to the UGRB that were federally approved by the EPA.

"We're not all the way down the road, yet. There is still work to be done. But through the continued collaboration and combined outreach efforts of the many stakeholders in the UGRB, we're moving in the right direction.

This document helps illustrate, in detail, where we've been, where we are, and where we're going. It's the story of how we're leading the way in the UGRB.

Together."

–Todd Parfitt
Director
Wyoming DEQ

UGRB BY THE NUMBERS

6: Consecutive years attaining the 8-hour standard for the 2008 ozone NAAQS (2012-2017).

2016: Year in which the EPA issued a Determination of Attainment of the 2008 Ozone NAAQS for the UGRB nonattainment area.

6,402: Tons of VOCs offset/reduced in UGRB through permitting from 2008-2017.

1,651: Tons of NOx offset/reduced in UGRB through permitting from 2008-2017.

1,987: Approx. number of facilities in the UGRB affected by the Existing Source Rule (which became compliance-date effective on January 1, 2017).

3: Number of state rulemakings pertaining to the UGRB since 2012.

5: Number of revisions to the WDEQ Oil and Gas Production Facilities Chapter 6, Section 2 Permitting Guidance since 2004.

605: Approx. number of WDEQ staff hours dedicated to winter ozone forecasting in the UGRB in 2017.

5,500: Approx. number of WDEQ staff hours dedicated to winter ozone forecasting in the UGRB since 2009.

259: Total number of annual Ozone Contingency Plans (OCPs) submitted between 2009 (when program was instituted) and 2017.

33: Total number of annual OCPs that were submitted in 2017.

13: Exceedances of the 8-hour standard for the 2008 ozone NAAQS (75 ppb) in 2011 winter ozone season.

4: Individual daily exceedances of the 8-hour standard for the 2008 ozone NAAQS (75 ppb) for the 2012-2017 winter ozone seasons (total).

3.19: Inches of precipitation at Big Piney from January - March 2017, which was the first season with elevated winter ozone since 2011.

1.1: Historical average for inches of precipitation during a winter ozone season (for the months of January - March) at Big Piney site.

75: Three-year design value for the 8-hour 2008 ozone NAAQS (in ppb).

70: Three-year design value for the 8-hour 2015 ozone NAAQS (in ppb).

62: Three-year design value for the Boulder monitor from 2015-2017 (in ppb).

OZONE ORIGINS

The discovery of elevated winter ozone in the UGRB in February 2005 wasn't merely a new development for the Wyoming Department of Environmental Quality – Air Quality Division. The winter ozone phenomenon was, itself, new to the regulatory community and had not yet been addressed by the Environmental Protection Agency (EPA). Even over a decade later, winter ozone is an extremely rare occurrence in the United States and we still don't entirely understand the factors that cause it to form; in 2005, virtually nothing was known about its formation.

As such, it was important that the Division thoroughly study winter ozone as part of its strategy for developing proactive measures to address elevated ozone concentrations in the UGRB. It's been a lengthy and sometimes time-consuming process, but the insights that have been revealed over the past 12-plus years have helped the Division develop regulatory and voluntary response measures that have eliminated thousands of tons of volatile organic compounds (VOCs) and

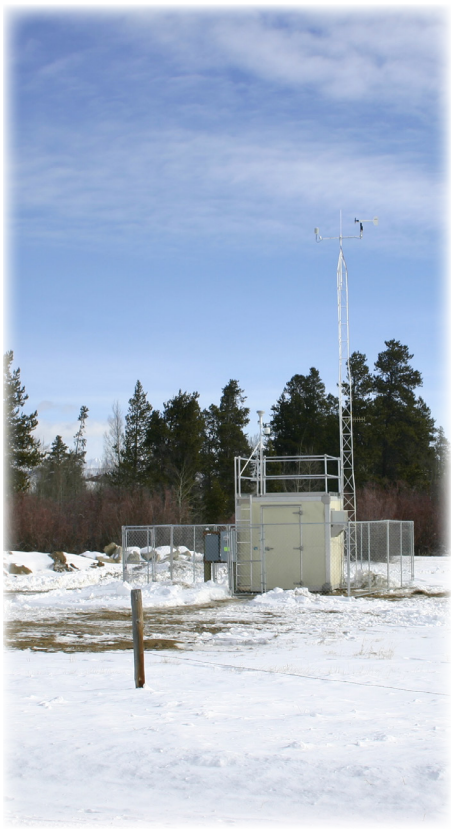
nitrogen oxides (NOx) pollutants.

LIFE BEFORE WINTER OZONE

Although the Division first began to monitor elevated ozone levels in the UGRB in 2005, the Division's involvement in the UGRB significantly predates the initial discovery of winter ozone. The Division was already involved in a variety of National Environmental Policy Act (NEPA)-related actions pertaining to oil and gas development and permitting. Regulatory presence in the area further predates this, as the Division first began issuing permits to oil and gas facilities in the area in the late 1990s. The Division had also started undertaking visibility studies with regard to air quality in the UGRB area as early as 1995, and frequently in the early 2000s.

The ambient air conditions in the UGRB truly were brought to the forefront in February 2005, however, when newly installed monitoring stations at the Boulder, Daniel, and Jonah locations – as well as the existing Pinedale CASTNet site – recorded elevated ozone concentrations on several days.

In 2005, there were three winter exceedances of the existing 1997 8-hour ozone standard of 84 ppb. The elevated ozone concentrations recurred in February 2006, alerting the Division that the initial elevated ozone readings were not an anomaly. This discovery ultimately prompted the Division to take a series of actions.



AQS Site ID	Site Name	Daily Max 8-hr Ozone Average (ppb)	Date of Observance
56-035-0098	Jonah	97	2/3/2005
56-035-0099	Boulder	81	2/3/2005
56-035-0099	Boulder	88	2/20/2005
56-035-0098	Jonah	88	2/26/2005
56-035-0100	Daniel South	82	2/25/2006
56-035-0098	Jonah	88	2/27/2006

Table 1. Daily Max 8-hr Ozone Exceedances in the Upper Green River Basin from 2005-2006.

In 2005 and 2006, newly installed monitoring stations in the UGRB recorded elevated ozone levels for the first time. These monitored days first alerted the citizens of the UGRB – and the Division – of the winter ozone issue. The table above displays the individual days of exceedance, as well as the sites at which the exceedances were monitored and the exceedance value (in parts per billion).

UNDERSTANDING THE UNKNOWN

The Division's meteorology staff conducted an extensive literature review of existing studies on stratospheric ozone intrusions and the roles that certain meteorological conditions can play in influencing their occurrence. The staff found that many of the observed conditions on the days that the exceedances occurred defied the trends of traditional stratospheric ozone intrusions. It became clear that we were observing something very new to the air quality regulatory community and that the situation called for much more extensive study.

There were already a few air quality monitoring stations (Boulder, Jonah, Daniel) that were newly installed at the time that elevated ozone readings were first observed. However, the WDEQ recognized the necessity for further action and established a shared-funding agreement with a group of industrial operators in the UGRB, referred to as "The Industry Participants' Group."

With the agreement, oil & gas industry operators and WDEQ shared a commitment to each provide 50 percent of $7,794,000 to support air quality monitoring, modeling, compliance monitoring, and other activities related to oil and gas development in Southwestern Wyoming.

This funding agreement provided the foundation for the extensive air quality monitoring network that now exists in the UGRB. Today, there are ambient air quality monitoring stations at 10 sites in Southwestern Wyoming.

Those monitoring stations have enabled the Division to more accurately and effectively assess and plan for the varying ambient air quality conditions in the Basin during winter ozone season and throughout the rest of the year. The installation of monitors, however, was just the first of many actions to come for the UGRB; our next steps truly laid the first bricks in developing a regulatory response to winter ozone formation.

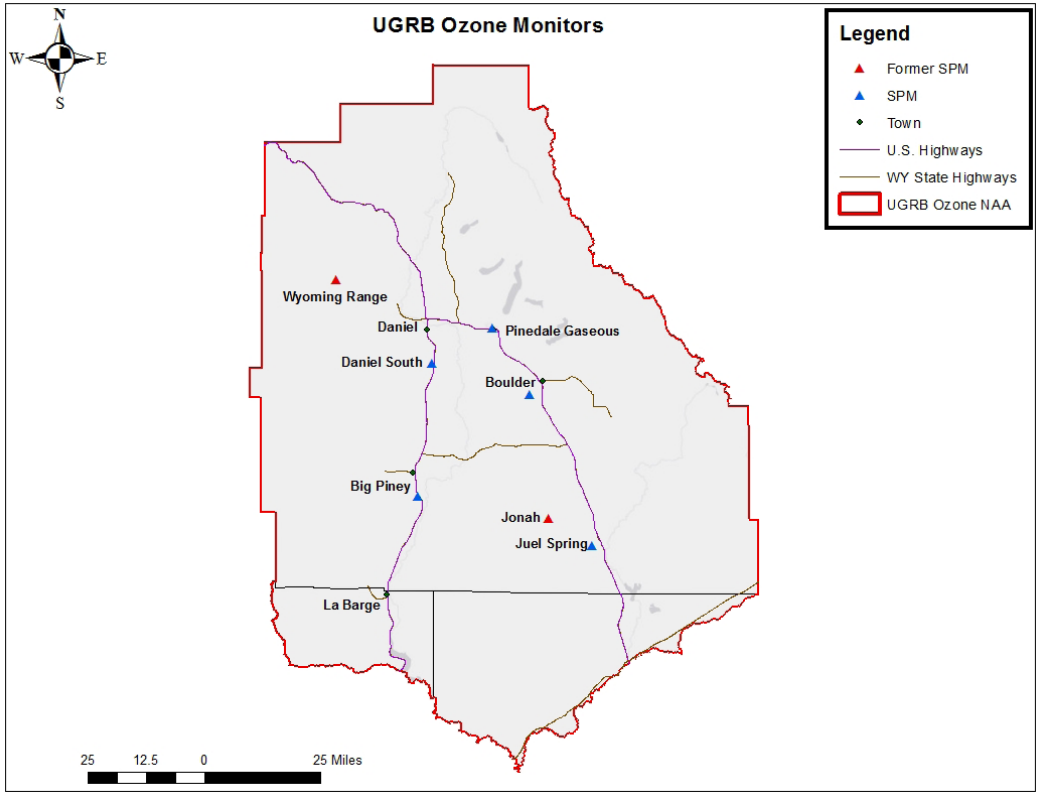
OUTREACH STORIES

Ensuring that the public is informed is always a primary objective for the Wyoming Department of Environmental Quality. In the case of the discovery of elevated ozone levels in the UGRB, the WDEQ took steps to enhance its WyVisNet website (www.wyvisnet.com) to better inform the public about monitored ozone concentrations and what they mean in terms of health impacts.

Meanwhile, a local elementary class helped raise further awareness of the ozone conditions in the UGRB. Operators in the UGRB also enacted early commitments to green completions, consolidation to multi-well pads, control of pneumatics, and evaluation of leaks using visual methods such as FLIR cameras. And citizens in the UGRB organized community interest groups and welcomed guest speakers to learn more about ozone and its health effects. The UGRB citizens also requested an air toxics study, and other health studies, from the Sublette County Commissioners. The Wyoming Department of Health also conducted health studies on ozone (*see UGRB Technical Work Compendium on page 60*).

INITIAL EMISSION INVENTORY

In early 2005, the Division met with operators in the Jonah/Pinedale Development Area and announced that the Division would conduct an emission inventory for 2004 to determine actual emissions of NOx, VOCs, sulfur dioxide (SO_2), and hazardous air pollutants (HAPs). This initial inventory helped provide insights into the emissions sources and pollutants in the area.



The above map depicts the UGRB nonattainment area and the current/former monitoring stations (SPMs), as well as towns and roads.

PROACTIVE MEASURES

Although in 2005 there was not a definitive explanation of how and why winter ozone forms in the UGRB, a variety of stakeholders began taking proactive steps to address the issue. The study of winter ozone was, of course, still in its initial stages. As such, these preliminary measures were not the pathway to an overnight solution. Instead, they laid the initial groundwork for developing comprehensive, enduring regulations and voluntary actions to address elevated winter ozone in the UGRB for years to come.

THE FIRST STEPS

The Division first developed specific guidance for Presumptive Best Available Control Technology (P-BACT) for the Jonah/Pinedale Anticline Development Area (JPAD) in its 2004 revision to WDEQ's Oil & Gas Guidance, where JPAD provisions were included as an addendum. In 2007, the Division took an additional step in its revision of the Oil & Gas Guidance. In those revisions, the Division increased the stringency of the P-BACT requirements, including those that applied to the JPAD, and formally included them as part of the Guidance.

In 2008, the Division developed the Interim Policy on Demonstration of Compliance with Chapter 6, Section 2(c)(ii) of WAQSR, introducing VOC and NOx offsets as a demonstration of compliance option for sources in Sublette County. The development of an Ozone Contingency Plan Program and a voluntary emission reduction policy for Sublette County followed in 2009 and 2011, respectively. These preliminary measures represent some of the scope of regulatory work that was already being undertaken prior to the UGRB's nonattainment classification in 2012.

RECORD OF DECISION ACTIONS

Prior to the development of the Interim Policy on Demonstration of Compliance, there were several federal actions by the U.S. Department of the Interior, Bureau of Land Management (BLM) that also applied to production facilities in the UGRB. The first was the 2006 Record of Decision (ROD) for the Jonah Infill Drilling Project. This action required the use of more stringent Tier II or equivalent diesel engine emission technologies for all drill rigs in the Jonah Field. As such, drill rig emissions that were potentially associated with ozone precursors (VOCs, NOx) were reduced.

A second ROD for the Pinedale Anticline Project Area (PAPA) was issued in 2008 requiring the installation of liquids gathering systems and the use of rig engine NOx controls in the PAPA area. These requirements helped reduce flashing emissions and truck traffic.

SIGNIFICANT EMISSION REDUCTION MEASURES (PRE-NONATTAINMENT)

As early as 2004, the Division worked with a variety of stakeholders in developing proactive measures to address the air quality in the UGRB.

Measure: Oil & Gas Guidance (*revised*)
When: 2004
Addressed: Oil & Gas Production Facilities in JPAD area
Outcome: Introduced the first P-BACT requirements for the JPAD area, including control requirements and application procedures for single well facilities, and control requirements and application procedures for multiple well or PAD facilities.

Measure: Addition of a compliance inspector in the UGRB
When: 2006
Addressed: Oil & Gas Production Facilities in the UGRB
Outcome: The introduction of the first compliance inspector in the UGRB helped the Division ensure that facilities in the UGRB were operating in accordance with regulatory requirements. Today, there are two full-time compliance inspectors at the WDEQ Pinedale office who perform regular inspections of facilities in the UGRB.

Measure: Oil & Gas Guidance (*revised*)
When: 2007
Addressed: Oil & Gas Production Facilities in JPAD area
Outcome: Established specific P-BACT permitting processes for sources/equipment in the JPAD area (including dehydration units, pneumatic pumps, flashing emissions, etc.)

Measure: Interim Policy on Demonstration of Compliance with WAQSR Chapter 6, Section 2(c)(ii)
When: 2008
Addressed: Natural Gas and Transmission Companies in Sublette County
Outcome: This policy required affected sources to submit ambient ozone modeling, demonstrate emission reductions/offsets for VOC and/or NOx emissions, or propose alternate demonstrations in order to meet the compliance requirements of Chapter 6, Section 2(c)(ii).

Measure: Voluntary Ozone Contingency Plan Program
When: 2009
Addressed: Contingency measures for Ozone Action Days
Outcome: Oil and gas operators in the UGRB developed short-term emission reduction plans that could be implemented with one-day notice given an impending forecast for weather conditions conducive to elevated ozone. Original measures included notification of personnel and contractors, the suspension and rescheduling of non-critical maintenance activities and liquids hauling, limiting vehicle and ancillary equipment idling, minimizing usage or turning off engines, refueling vehicles after dark, and implementing a traffic minimization program.

Measure: Oil & Gas Guidance (*revised*)
When: 2010
Addressed: Oil & Gas Production Facilities in JPAD area
Outcome: Revised P-BACT requirements for facilities in the JPAD area, specifically 98% flashing emissions controls for new/modified facilities emitting over 8 tons per year of VOC/HAP emissions, pneumatic devices, etc.

Measure: Sublette County Banking/Voluntary Emissions Reduction Policy
When: 2011
Addressed: Sources in Sublette County
Outcome: Developed offset criteria for production sites/compressor engines permitted prior to July 2008, and constructed, reconstructed, or modified after July 2008, in order to provide companies with incentives to make voluntary VOC and NOx emission reductions above and beyond requirements.

WHAT IS AN OFFSET?

Emissions offsets are a permitting function that require an emission reduction of a specific pollutant that is equivalent or greater than a proposed emission increase of that specific pollutant.

NONATTAINMENT CLASSIFICATION

On March 12, 2009, then-Wyoming Governor Dave Freudenthal submitted a recommendation to the EPA for the UGRB to be classified as a nonattainment area based on a WDEQ staff analysis. The EPA acted on this recommendation on July 20, 2012, when the UGRB was classified as a "marginal" nonattainment area for the 2008 ozone NAAQS by the EPA. This designation was based on monitored data including the 2008 winter ozone season, where there were 14 exceedances of the 75 ppb standard set by the 2008 NAAQS. The three-year average of the fourth-highest 8-hour daily maximum ozone concentration (also known as the "ozone design value") of 2008-2010 exceeded 75 ppb, resulting in the nonattainment classification.

Furthermore, the 2011 winter ozone season witnessed meteorological conditions that were especially conducive to ozone formation. Bolstered by extraordinarily high snow accumulation (snow depths of 17 inches at the Boulder Station), there were 13 exceedances of the 2008 standard.

Taken together, the 2008 and 2011 winter ozone seasons made it clear that – despite the initial emission reduction strategies developed prior to its nonattainment classification – it would take a much more extensive team effort from the Division and all stakeholders in order to address the ozone issue in the UGRB.

UP TO THE TASK

The nonattainment classification was a new challenge for the State, as it was Wyoming's first marginal nonattainment area for winter ozone. Furthermore, given that scientific understanding was at its infancy regarding the connection between ozone precursor emissions, meteorology, and other factors associated with the formation of winter ozone made the development of effective regulations especially challenging. It required a comprehensive effort – and stakeholders from all perspectives stepped up to the task at hand.

In 2012, at the direction of Wyoming Governor Matt Mead, a Citizens Advisory Task Force was assembled to consider and advise on potential solutions to reduce ozone. The Task Force consisted of 28 members representing a complete spectrum of stakeholders – concerned citizens, environmental groups, industrial operators, local government, county government, state government, and federal government.

The objective? To transparently communicate, educate, and develop practical, effective, consensus recommendations. It was an extensive process, with seven meetings in 2012, and culminating with the Task Force issuing a series of final consensus recommendations in September 2012. The recom-

mendations included undertaking rulemakings addressing uncontrolled VOCs from existing sources, leak detection and repair (LDAR), produced water and storage, and other strategic measures for record-keeping, monitoring, and emission reductions. Ultimately, those recommendations helped lay the groundwork for a path forward in developing a comprehensive ozone strategy – a landmark in the regulatory response to elevated winter ozone in the UGRB.

HOW IS THE DESIGN VALUE CALCULATED?

An individual daily exceedance of the 8-hour ozone standard does not automatically mean that an area will be subject to a nonattainment classification. The EPA instead uses a calculation called the ozone design value to make nonattainment/attainment classifications for specific areas.

The design value for the Primary and Secondary 2015 ozone NAAQS (as well as the 2008 ozone NAAQS) is determined by averaging the annual fourth-highest daily maximum 8-hour concentration over three years. During the course of a day, rolling 8-hour averages are computed from hourly concentrations.

The Juel Spring Air Quality Monitoring Station began operations in December 2009.

The highest rolling average is considered the daily maximum. The daily maximum 8-hour concentrations for a given year are then ranked, and the fourth-highest concentration of a specific year is selected as that year's design value. The yearly design values from consecutive three-year periods are then averaged to produce the NAAQS-comparable design value. Three-year design values less than 70 ppb are considered to be in compliance with the 2015 ozone NAAQS (75 ppb for the 2008 ozone NAAQS).

ELEVATED SNOW TOTALS, ELEVATED WINTER OZONE

One correlation with elevated ozone formation in the UGRB has been the prevalence of high snowfall totals in the three most active years for elevated ozone (2008, 2011, 2017). In both 2008 and 2011, snow depths surpassed 15 inches at the Boulder Rearing Station. In 2017, record snowfall amounts of 22 inches were measured at the Boulder Rearing Station from January 25 - February 2.

CONTINUED COLLABORATION

The elevated winter ozone response measures that we implement today took full form in 2013. The Division considered the Task Force recommendations and worked quickly to develop proactive regulations as we began to address the Clean Air Act requirements for ozone nonattainment areas.

First, in April 2012, the Division began participating in the EPA's Ozone Advance Program, which provided a structure for developing local actions and timelines for reducing emissions. In March 2013, the Division released its first Ozone Strategy for the UGRB, which set a series of policy activities and objectives that were based in part on the recommendations from the Task Force.

The initial Strategy included several practices that became foundational elements of the Division's UGRB outreach – including winter ozone forecasting and the Upper Green Winter Ozone Study (UGWOS) – and subsequent revisions to the strategy followed in the ensuing years.

2013 also marked the first year that the Ozone Contingency Plan Program (including Ozone Action Day/Ozone Contingency Plan measures) expanded to all stakeholders, including government agencies and the general public.

THE EXISTING SOURCE RULE

The next several years brought a series of new regulations and actions that furthered the air quality improvements in the UGRB. One significant development was a solution tailored to the UGRB, the UGRB Permit by Rule for Existing Sources – a two-year process that became a state-effective rule on May 19, 2015.

Members of the public listen to a presentation on the Existing Source Rule at a December 2014 Air Quality Advisory Board meeting at the Pinedale Library.

The Existing Source Rule, as it came to be known, established a series of requirements for PAD (multi-well facility) and single-well oil and gas production facilities, and compressor stations, located in the UGRB that existed as of January 1, 2014. Most notably, the rule placed the same control thresholds on existing sources as it did for new and modified ones; for applicable sources, as defined in the rule, 98% controls must be placed on equipment emitting more than four tons per year of uncontrolled VOCs, among other requirements.

The Existing Source Rule became compliance-date effective on January 1, 2017, the required control installation date for all applicable sources. Today, the Rule represents a milestone team effort in reducing ozone precursors in the UGRB and addressing the area's nonattainment concerns.

TAKING THE NEXT STEPS

Upon its classification as a marginal nonattainment area for the 2008 ozone NAAQS, the UGRB stepped front-and-center as an area of focus for the Division and all stakeholders in the area.

In addition to the following measures, the Division also collaborated with regional and national scientists, engineers, and air modelers to form a technical advisory group to better understand the science behind winter ozone formation and how to model for it. We also began to collaborate with the Uintah Basin in Utah, which also had winter ozone exceedances in an area of oil and gas development.

Measure: UGRB Air Quality Citizens Advisory Task Force
When: 2012
Addressed: Advising on potential solutions to reduce ozone
Outcome: The Task Force met seven times in 2012, ultimately providing 10 consensus recommendations for regulatory and emission reduction measures for addressing ozone in the UGRB.

Measure: Ozone Advance Program
When: 2012
Addressed: Winter ozone formation in the UGRB
Outcome: Participation in this voluntary program helped better position the State of Wyoming to plan its "path forward" by setting a number of near-term strategies (regarding measures and programs to reduce VOCs and NOx emissions) and long-term strategies (programs to be developed and implemented over time) to address elevated winter ozone.

Measure: Oil & Gas Guidance (*revised*)
When: 2013
Addressed: Production facilities located in the UGRB and JPAD/NPL
Outcome: Developed specific P-BACT requirements for the UGRB (outlining the geographic area for the UGRB), and JPAD/NPL, including lower control thresholds for TPY of VOCs and HAP flashing emissions, as well as LDAR provisions for fugitive emissions.

Measure: Voluntary Ozone Contingency Plan Program
When: 2013
Addressed: Contingency measures for Ozone Action Days
Outcome: The program was expanded in 2013 to include governmental agencies/entities and expanded further in 2017 to include the public as participants.

Measure: Ozone Strategy for the UGRB
When: 2013-2016
Addressed: Ozone reductions for the UGRB
Outcome: DEQ's overall ozone reduction strategy included Task Force consensus recommendations and many other elements focused on a six-month timeframe and groups of activities based on when they were targeted to start or be accomplished. The strategy and associated document was developed to evolve over time based on consideration of the status of strategy elements, new information, and staff resource demands.

The initial *UGRB Ozone Strategy* was dated March 11, 2013, with six subsequent strategy documents dated September 24, 2013; April 22, 2014; October 21, 2014; April 28, 2015; October 28, 2015; and April 29, 2016. The completed elements from all strategy documents have been important in building the foundation to bring the UGRB back into attainment of the ozone NAAQS. The April 29, 2016 *UGRB Ozone Strategy* was the final evolution of the strategy in document form.

Measure: General Conformity SIP Revision
When: 2013
Addressed: Clean Air Act requirements for demonstrating General Conformity
Outcome: This revision to WAQSR Chapter 8, Section 3 ensured that Wyoming retained primacy by confirming that federal actions in the UGRB conformed with the Division's plans addressing nonattainment and would not cause or contribute to an exceedance of the ozone NAAQS. The EPA issued a final approval of the General Conformity SIP revision on August 15, 2013.

Measure: Ozone Nonattainment Emission Inventory Rule and SIP Revision
When: 2014
Addressed: Clean Air Act Section 182 requirements
Outcome: Established requirements for the submittal of emission inventories from facilities or sources located in an ozone nonattainment area. The EPA issued a final approval of the State of Wyoming's SIP revision for WAQSR Chapter 8, Section 5 on August 25, 2016.

Measure: UGRB Permit by Rule for Existing Sources
When: 2015

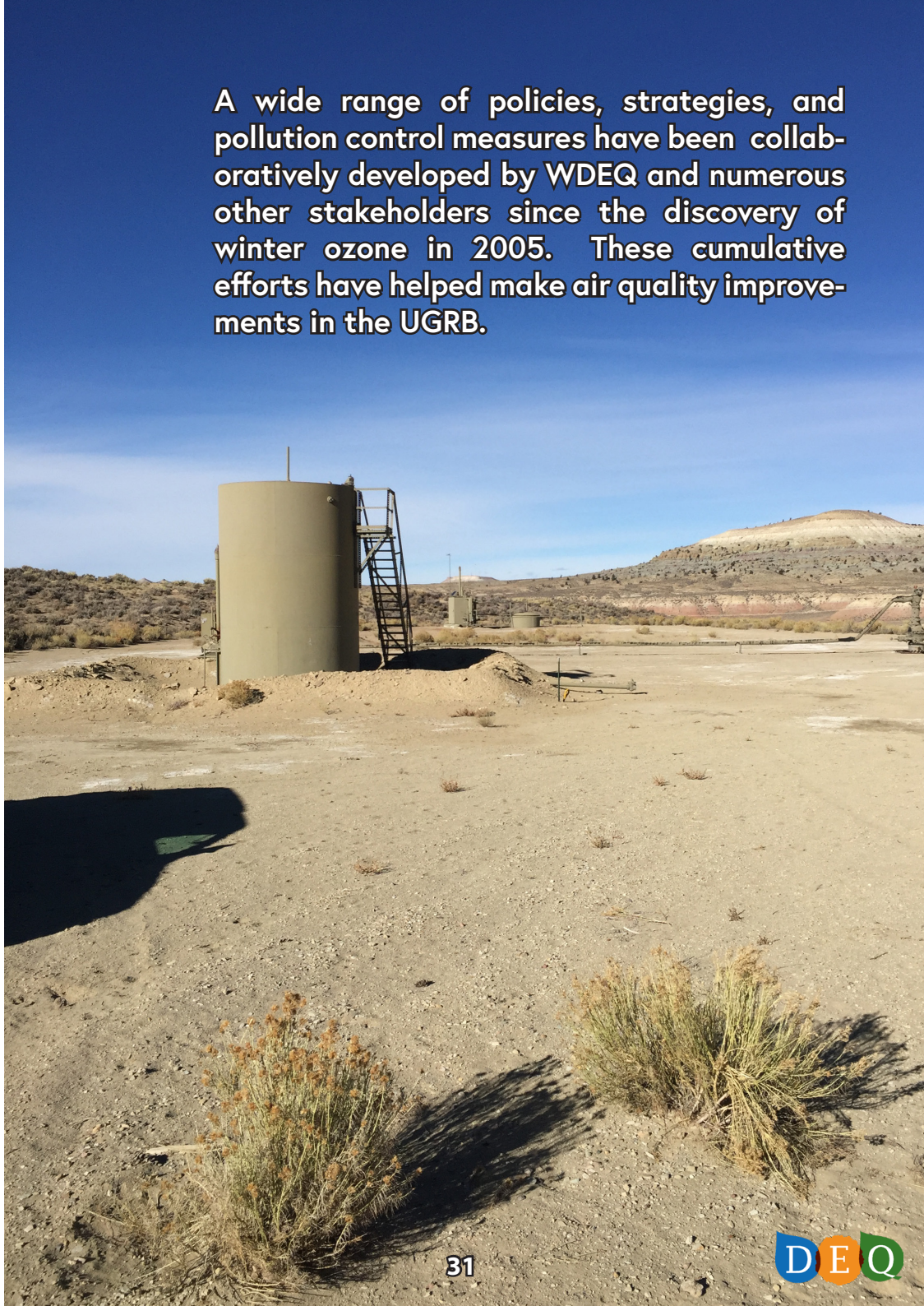
Addressed: Existing oil and gas production facilities, and compressor stations, located in the UGRB nonattainment area
Outcome: The Existing Source Rule – WAQSR Chapter 8, Section 6 – established pollution control, monitoring, recordkeeping, and reporting requirements for PAD and single-well oil and gas production facilities, and compressor stations, located in the UGRB that were existing as of January 1, 2014.

The requirements addressed reducing VOC and HAP emissions from flashing, dehydration units, pneumatic pumps, pneumatic controllers, fugitive emissions, storage tanks, etc.

Measure: Nonattainment New Source Review Regulations and SIP Revision
When: 2015
Addressed: New and modified major stationary sources in a nonattainment area
Outcome: The Division revised WAQSR Chapter 6, Section 13 to incorporate federal regulatory language establishing more rigorous permitting requirements (including Lowest Achievable Emission Rate – or LAER – analysis) for new and modified major stationary sources in a nonattainment area. The EPA issued final approval of the State of Wyoming's SIP revision for Chapter 6, Section 13 on June 6, 2016.

Measure: Oil & Gas Guidance (*revised*)
When: 2016
Addressed: Production facilities located in the UGRB and JPAD/NPL
Outcome: This revision lowered allowable emissions rates by incorporating the existing concentrated development area (CDA) requirements and applying them statewide. It also added a threshold for truck loading in the UGRB and JPAD/NPL. This revision additionally incorporated New Source Performance Standards (NSPS) Subpart OOOO and OOOOa requirements into the Guidance.

A wide range of policies, strategies, and pollution control measures have been collaboratively developed by WDEQ and numerous other stakeholders since the discovery of winter ozone in 2005. These cumulative efforts have helped make air quality improvements in the UGRB.



THE FORECAST FOR SUCCESS

The winter ozone season can be one of the busiest times of the year at the Division, especially for key members of its staff. The Division currently employs several meteorologists in its Air Quality Resource Management (AQRM) Program who forecast for winter ozone in the UGRB. Winter ozone forecasting typically begins in January of each year and runs until the end of March.

That stretch marks a rigorous period where forecasters are focused on assessing weather models and meteorological conditions in the UGRB to determine whether they are conducive to the formation of elevated ozone. The forecasting team does not forecast a specific value for ozone, but rather assesses specific parameters and variables in order to determine whether a proactive response for predicted elevated ozone needs to be issued in the way of an Ozone Action Day.

NAVIGATING THE VARIABLES

There are certain recurring meteorological trends with which the formation of elevated winter ozone tends to correspond. Strong temperature inversions, deep snowpack and light winds are a few of the conditions that have been routinely observed during elevated ozone formation.

However, it is not a straightforward forecasting process. Forecasters and scientists alike face a difficult challenge in solving why winter ozone forms. Weather models can change quickly, and the area's complex geographic terrain poses additional challenges to the models.

Furthermore, the area's geographic sparseness means that there are limited observation points at which data can be gathered – necessary to provide accurate upper-level air data – and the general shortfall of data makes identifying trends difficult. Additionally, there are variabilities in the reactions of certain pollutants that can also influence winter ozone formation. The Division's forecasting team assesses the available information and applies its expertise in determining whether an Ozone Action Day should be issued.

Ultimately, forecasting helps the Division inform the entire area of potential elevated ozone and gives operators, municipal entities, and citizens a head start on implementing contingency measures that can make a difference in lowering precursor emissions.

A DAY IN THE LIFE OF A DEQ WINTER OZONE FORECASTER

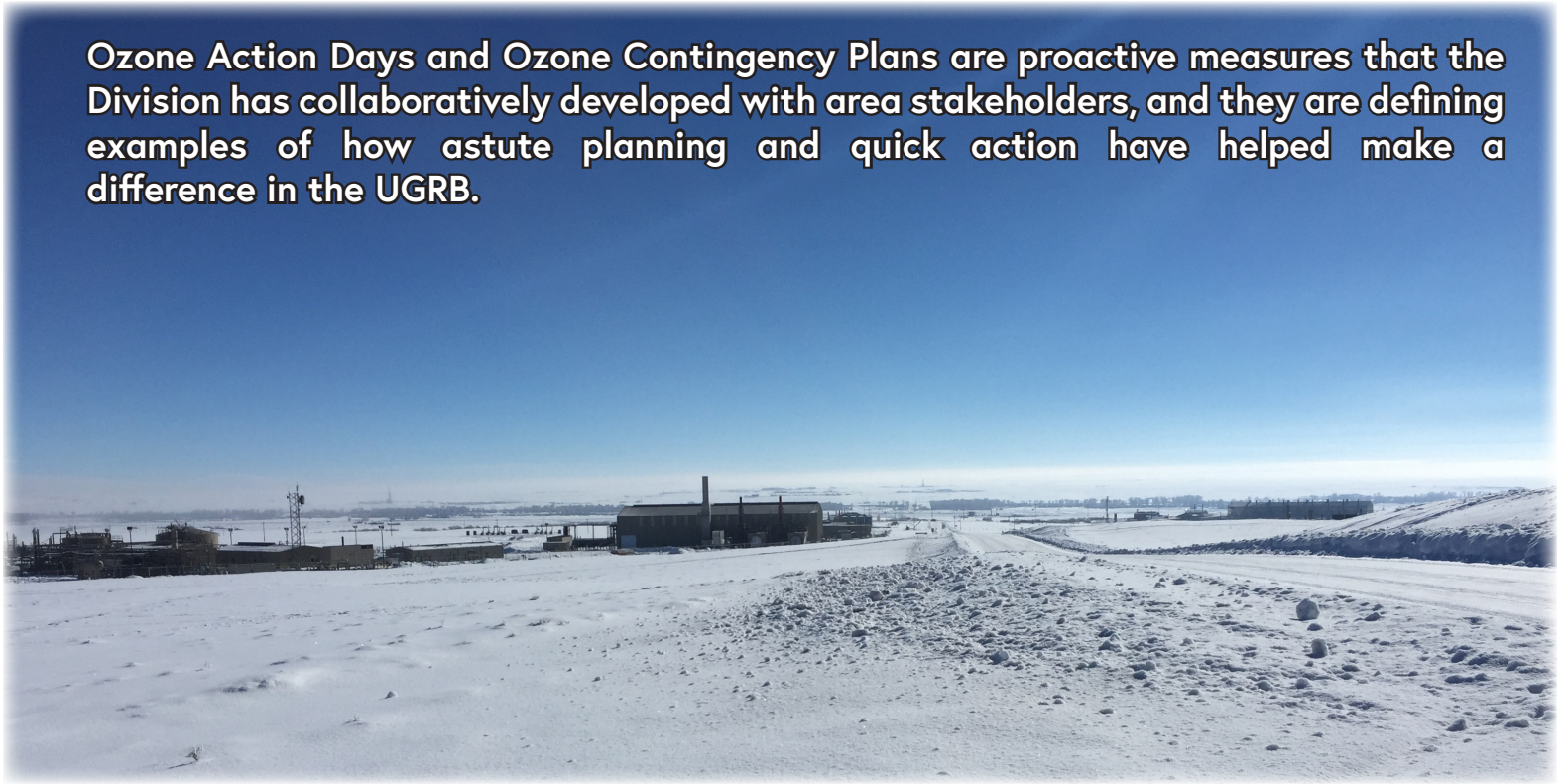
7:30 a.m.: Forecasters independently observe current weather conditions in the UGRB and examine webcams. They also assess the previous day's ozone values and the previous day's forecast. Forecasters independently observe the most updated weather models for the UGRB, use forecasting tools including weather forecasting models such as the Global Forecast System (GFS), North American Mesoscale (NAM), and European Centre for Medium-Range Weather Forecasts (ECMWF, or "Euro"), and enter data into a checklist (pertaining to conditions that often correlate with winter ozone formation) to determine whether an Ozone Action Day is warranted or a possibility.

10:00 a.m.: Forecasters convene to discuss the forecast.

10:30 a.m.: Forecasters meet with management to evaluate the forecast and determine whether an Ozone Action Day should be issued.

11:00 a.m.: If an Ozone Action Day is determined to be warranted, it is issued by the Division by noon, alerting all stakeholders with one day of notice.

ABOVE AND BEYOND



Ozone Action Days and Ozone Contingency Plans are proactive measures that the Division has collaboratively developed with area stakeholders, and they are defining examples of how astute planning and quick action have helped make a difference in the UGRB.

When WDEQ forecasters and management determine that forthcoming meteorological conditions present concerns of winter ozone formation, they will issue an Ozone Action Day (OAD).

An Ozone Action Day indicates that Ozone Contingency Plan (OCP) participants (oil and gas operators, governmental agencies/entities, and the public) will implement voluntary, short-term emission reduction measures in order to take all steps possible to minimize ozone formation.

It's another proactive measure that the Division has collaboratively developed with area stakeholders, and it's a defining example of how astute planning and quick action make a difference in the UGRB.

Oil and gas operators, and other participants, get a head start on Ozone Action Day measures by submitting Ozone Contingency Plans that identify the specific activities that can be implemented with one day of notice. Some of the measures implemented in the OCPs include:

- ✔ Deferring non-essential construction and maintenance activities
- ✔ Delaying the refueling of trucks and equipment
- ✔ Eliminating truck idling whenever possible
- ✔ Encouraging carpooling or teleworking whenever possible
- ✔ Cancelling well venting

Ultimately, it's a shared effort between operators and other participants in the UGRB who take precautionary measures that minimize ozone impacts. Those efforts continue to play an important role in ozone mitigation.

2017: PUTTING OZONE ACTION DAYS AND OZONE CONTINGENCY PLANS INTO ACTION

In the 2017 winter ozone season, 33 total annual OCPs were submitted, and the Division issued 12 OADs for the UGRB. The winter ozone season was the most active in the UGRB since 2011 (*see "2017: A Closer Look" on page 52*). Despite record-breaking snowpack levels that persisted during intervals of the 2017 season, the four exceedances of the 2008 ozone NAAQS (75 ppb) in 2017 were significantly fewer in comparison to 13 in 2011 and 14 in 2008 (the other two highest snowpack years in recent history).

In 2017, the UGRB also had seven exceedances of the new, lower 2015 ozone NAAQS (70 ppb). However, the UGRB is still at-

taining the 2015 standard based on a three-year average of the fourth-highest daily maximum concentration, also known as the **"ozone design value."** And, the EPA recently designated the UGRB as attainment/unclassifiable for the 2015 ozone NAAQS.

The proactive response through the implementation of OCPs and OADs helped minimize emissions and, by extension, ozone impacts on days that were favorable for elevated ozone formation.

HOW THE OZONE DESIGN VALUE IS CALCULATED

The design value for the Primary and Secondary 2015 ozone NAAQS is determined by averaging the annual fourth-highest daily maximum 8-hour concentration over three years.

Moving 8-hour averages are computed from hourly concentrations on a daily basis, the highest of which is considered the daily maximum. The daily maximum 8-hour concentrations for a given year are then ranked, and the fourth-highest concentration is identified.

The yearly fourth-highest values from consecutive 3-year periods are then averaged to produce the NAAQS-comparable design value. Finally, 3-year design values less than or equal to 70 ppb (0.070 ppm) are then considered to be meeting the NAAQS.

OCPs AND OADs: 2017 BY THE NUMBERS

33: Total annual OCPs submitted to the Division

25: Average number of organizations that alerted all personnel and service company staff of OAD status and contingency plan implementation

25: Average number of organizations that minimized the idling of vehicles and engines associated with energy recovery and production

25: Average number of organizations that successfully avoided overfilling gas tanks and tightened fuel caps on vehicles associated with energy recovery and production

24: Average number of organizations and affiliated service companies that deferred truck and equipment refueling to evening hours

17: Average number of organizations and affiliated service companies that used leak detection techniques to prevent and fix the venting of gas

12: Total OADs issued by the Division

LEARNING FROM STUDYING

Because so much of winter ozone was, and continues to be, a field of discovery for the Division – and for the scientific community – undertaking scientific study and observation in the UGRB has been a critical component of the Division's efforts. In 2007, the Division

instituted the Upper Green Winter Ozone Study (UGWOS) program. The UGWOS program is based on an initial plan, with documented measures to ensure quality, and results are issued through a final report.

The study assessed a variety of different measurements, including Mesonet Ozone measurements, VOC and Carbonyl measurements, Tethered Soundings operations, Ozone/Rawinsondes, and other intensive monitoring methods – as well as long-term monitoring station operations.

Now that roughly a decade has passed, the UGWOS has yielded some important results. The study has revealed key insights into the influence of meteorological conditions on the formation of winter ozone, specifically that the atmospheric height of the inversion layer and the amount of snow cover on the ground both play important roles in ozone formation. Several other illuminating results from the UGWOS study include:

✘ Observing long-term trends of speciated VOCs (assessing VOC reductions in relation to operations in the UGRB over time)
✘ Assessing the spatial variation of ozone formation

across the UGRB (how terrain variability and other factors result in different VOC characteristics in certain parts of the UGRB)
✘ Examining the different species of NOx (how they react with snow and how they contribute to ozone formation in the UGRB)

Ultimately, the UGWOS has been a valuable undertaking for the Division because it has yielded data identifying some of the key pollutants to be controlled in order to reduce ozone precursor impacts. The Division has applied this data in modeling to discern specifically which pollutants have contributed to ozone formation, and thus, which pollutants are most important to control. This has helped inform and tailor policy and operations unique to the UGRB.

For a complete, detailed list of all studies undertaken in the UGRB, please see the compendium at the conclusion of this summary, entitled "*UGRB Technical Work Compendium*."

COMMERCIAL OILFIELD WASTE DISPOSAL POND STUDY

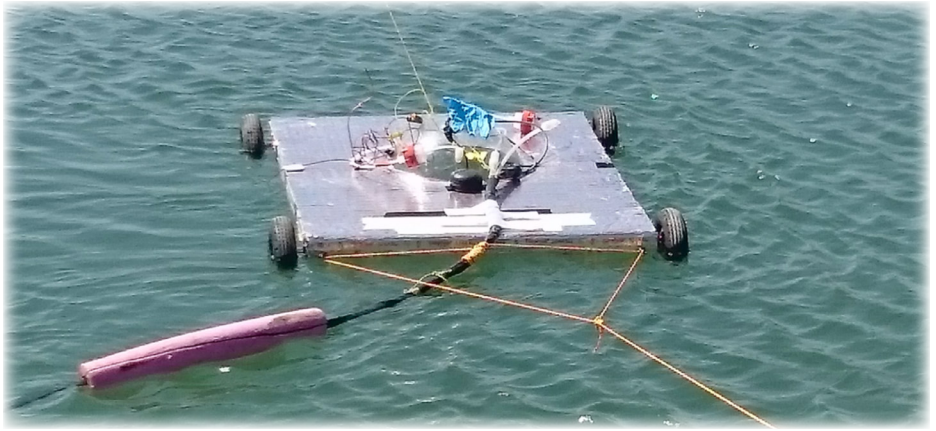
Another study that the Division has undertaken in the UGRB is the Commercial Oilfield Waste Disposal (or COWD) Pond Study. Produced water was an area of focus identified by the UGRB Task Force, and the Division set out to study potential emissions of VOCs and HAPs emanating from the ponds. The Division began studying the ponds, and in 2014, issued a contract

to develop an emission estimation methodology for the COWD ponds.

The pond study remains an ongoing project for the Division, but it has already helped us better understand how the air emissions emanating from the ponds are related to the water composition of the ponds. It has shed light on developing a long-term method that further illustrates the relationship between water compositions and air emissions, and it will help inform better emission inventories and permitting practices in the future.

Furthermore, it has allowed the Division to characterize a source that had not been previously studied, helping break new scientific ground with discoveries such as observations related to COWD pond emissions when the ponds are frozen.

We're still studying – and still learning – but these observations and discoveries ultimately enable us to more efficiently identify and reduce the precursor pollutants that contribute to winter ozone formation.



WHAT IS MODELING?

Modeling is the act of using a computer model to try to replicate pollutants in the air; a simulation that is either predictive or a replication of previous conditions.

THE USUAL SUSPECTS

The most commonly occurring pollutants at COWD ponds in the UGRB are the following:

- Methanol
- Benzene
- Toluene
- Xylenes
- Formaldehyde (less common)

SUCCEEDING TOGETHER

The EPA's issuance of a final Determination of Attainment on April 11, 2016 was an important first step towards redesignation and marked another milestone in the collaborative effort to improve the air quality in the UGRB.

SUCCEEDING TOGETHER

The hard work dedicated to developing and implementing regulations and voluntary contingency measures has already helped make a tangible impact in the UGRB. Although our work is not done, there has been noticeable progress in the cumulative air quality that has been monitored in the UGRB over the last several years.

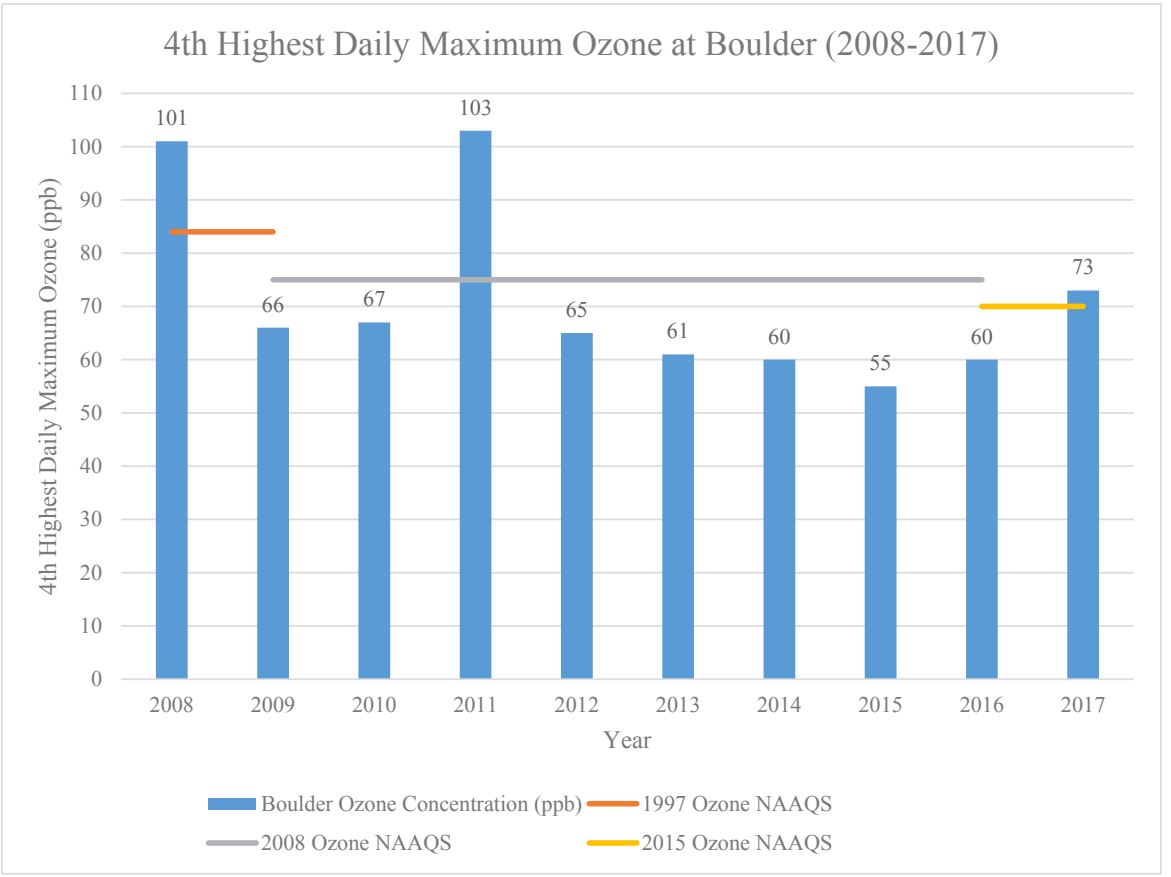
A comparison of monitored data from the onset years where winter ozone was first discovered (2005-2011) to the years in which regulatory framework had been developed to address its formation (2012-present) demonstrates some positive reduction trends.

In 2005, 2008, and 2011, there were 7, 14, and 13 exceedances, respectively, of the 2008 8-hour daily ozone NAAQS (75 ppb). Between 2012 and 2016, there was not a single winter exceedance of the 2008 ozone NAAQS (though there were two exceedances in June 2012). This ultimately resulted in the EPA's promulgation of a final Determination of Attainment for the UGRB nonattainment area on April 11, 2016.

During a 2017 winter where record snowfalls were observed, there were 4 exceedances of the 2008 8-hour daily ozone NAAQS (and 7 of the more stringent 2015 8-hour daily ozone NAAQS, which is 70 ppb). Those totals are significantly fewer, and were of a lower magnitude, than what occurred during the snowy seasons of 2008 and 2011 (*for more information on the 2017 winter ozone season, see the section entitled "2017: A Closer Look" on page 52*).

COMPARING DATA: 2006-2011 VS. 2013-2017

These reductions are further illustrated when we examine the ozone design values from 2013 to 2017 in comparison to those from 2006 to 2011. The ozone design value averages the fourth-highest daily maximum 8-hour ozone concentration over a three-year span, and is used to determine whether an area is attaining a respective ozone NAAQS.



From 2013 to 2016, the fourth-highest daily maximum concentration never exceeded 61 ppb, yielding a three-year design value of 58 ppb for the years 2014-2016. This is a significant departure from 2006-2008, where the three-year design values were 80 ppb, and from 2009-2011, where the three-year design values were 78 ppb.

Even when we examine the data from 2017 – where the fourth-highest daily maximum 8-hour ozone concentration was 72 ppb – the three-year average yielded a design value of 62 ppb. This value is in attainment with both the 2008 ozone NAAQS (75 ppb) and the 2015 ozone NAAQS (70 ppb).

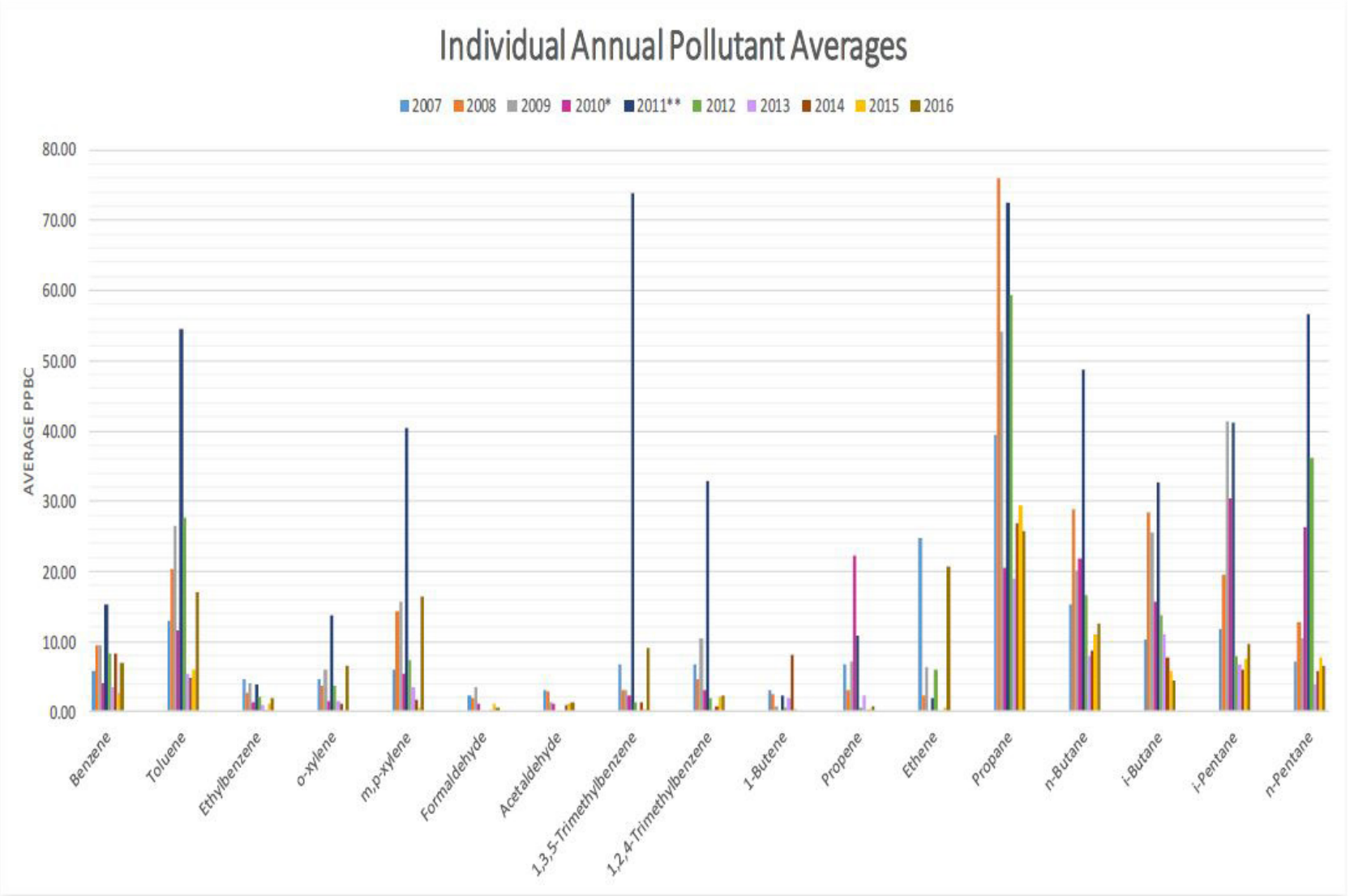
RECOGNIZABLE REDUCTIONS

Perhaps the most telling metric of progress are the thousands of tons of VOCs and NOx emissions that have been offset and reduced in the UGRB since 2008.

These offsets are the result of significant collaboration that has been undertaken by stakeholders in the UGRB since 2005, and they are an example of just how much we can continue to accomplish through strategic partnership. As of 2017, 6,402 tons of VOCs and 1,651 tons of NOx had been offset and reduced through WDEQ permitting since offsets were tracked in 2008.

Additionally, there have been immense reductions in individual pollutants, as well.

For example, 1,3,5-Trimethylbenzene has been reduced by nearly eight times of its 2011 levels, Propane has been cut by more than half, and n-Pentane is at roughly one-sixth of its 2011 levels. It's a measurable demonstration that the measures we all have implemented, and continue to implement, are making a difference in the UGRB.



* 2010 data used the average of all stations in the specific O&G field

** 2011 data used a tethered balloon near the Boulder Station

DETERMINATION OF ATTAINMENT

On April 11, 2016, the EPA promulgated a final determination of attainment for the UGRB nonattainment area for the 2008 ozone NAAQS in the Federal Register.

This meant that the EPA had determined that the UGRB had attained the 2008 ozone NAAQS of 75 ppb averaged over three consecutive years in the time since being designated as a nonattainment area.

The EPA's determination is not the same thing as a redesignation to attainment; that process is much more extensive and, upon completion, formally changes the area's classification from "nonattainment" to "attainment. This full process is displayed in the Division's efforts in completing a successful redesignation to attainment for the City of Sheridan PM_{10} nonattainment area in April 2018.

The Determination of Attainment is, however, the first milestone in the criteria established in the Clean Air Act for completing a request for redesignation to attainment. And, in the case of the UGRB, it is another indication that we are moving in the right direction.

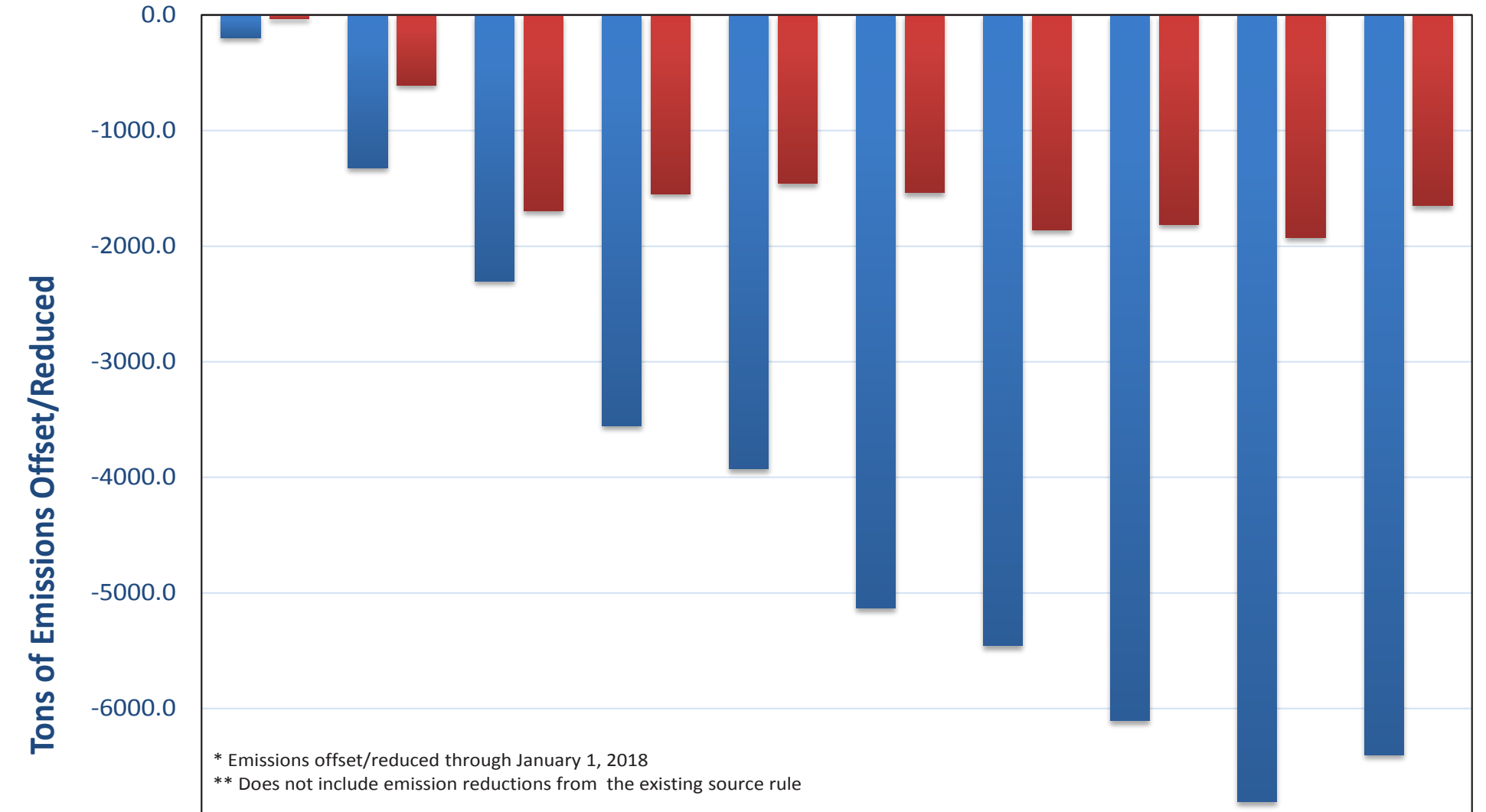
Winter Days with ozone levels above applicable standards by year since 2005 (just the UGRB)

O_3 NAAQS	2005	2006	2007	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
1997 (84 ppb)	**3**	**1**	**0**	**7**	0	0	6	0	0	0	0	0	1
2008 (75 ppb)	7	2	0	14	**0**	**0**	**13**	**0**	**0**	**0**	**0**	0	4
2015 (70 ppb)	11	3	1	14	0	0	16	0	0	0	0	**0**	**7**

4th highest daily max ozone at Boulder (2008-2017)

Year	2008	2009	2010	2011	2012	2013	2014	2015	2016	2017
Concentration (ppb)	101	66	67	103	65	61	60	55	60	73

Tons of VOCs and NOx Emissions Offset/Reduced Through Permitting



	2008	2008-2009	2008-2010	2008-2011	2008-2012	2008-2013	2008-2014	2008-2015	2008-2016	2008-2017
Total VOCs Offset	-196.6	-1322.1	-2302.2	-3555.1	-3926.9	-5129.9	-5455.4	-6104.8	-6806.0	-6401.0
Total NOx Offset	-33.6	-606.7	-1695.2	-1545.7	-1457.2	-1537.0	-1857.6	-1810.7	-1923.5	-1650.5

2017: A CLOSER LOOK

The 2017 winter ozone season was the most active year in the Basin since 2011, when there were 13 exceedances of the 8-hour daily 2008 ozone NAAQS.

In similar fashion to the 2011 season, 2017 saw significantly above-average snowfall totals throughout the UGRB – and, for nearly the first two months of the season, snowfall totals that were significantly greater than in 2011. From January 3 – February 10, record snowfall depths were measured at the Boulder Rearing Station, peaking at roughly 22 inches from a span of January 25 – February 2. Meanwhile, at Big Piney, total precipitation was recorded at 319 percent, 214 percent, and 329 percent of average levels for January, February, and March 2017, respectively.

The harsh winter conditions persisted throughout the 2017 season and played a role in the first-recorded winter ozone season exceedance of a daily 8-hour ozone standard since the 2011 season. On January 18, ozone levels of 72 ppb were measured at the Boulder Station, exceeding the 2015 ozone NAAQS (although they were still under the threshold for the 2008 ozone NAAQS). The next day, another reading of 77 ppb was recorded at Boulder, at concentrations above both NAAQS.

In total, there were seven individual days where at least one monitor was in exceedance of the 2015 ozone NAAQS and four days where at least one monitor exceeded the 2008 ozone NAAQS value of 75 ppb. The highest-recorded ozone level was 85 ppb, recorded at the Boulder Station on March 4, 2017; four other monitoring sites in the UGRB also recorded concentrations above 75 ppb.

DIGGING DEEPER INTO THE NUMBERS

Although there were elevated concentrations, the 2017 design value of 73 ppb is lower than, and in attainment of, the 2008 ozone NAAQS of 75 ppb.

When viewed in isolation as a single year, the 73 ppb level appears to exceed the 70 ppb level of the 2015 ozone NAAQS; it is a three-year average, however, that the EPA considers when determining compliance with the NAAQS and attainment/nonattainment classifications. As such, the three-year design value of 62 ppb for 2015-2017 is still well below both the 2008 and 2015 ozone NAAQS, and the area is still attaining both standards.

To be certain, there were elevated ozone levels in the UGRB in 2017. However, by comparison to the worst days recorded in 2008 (122 ppb) and 2011 (123 ppb), the 85 ppb recorded at the Boulder Station on March 4, 2017 was of significantly lower magnitude considering comparable winter conditions.

Similarly, the fourth-highest maximum was significantly lower than the ones measured in 2008 (101 ppb) and 2011 (103 ppb). In addition to the regulatory and other measures, the proactive responses of 12 Ozone Action Days may have helped minimize ozone impacts in 2017. Despite favorable meteorological conditions for winter ozone throughout the season, the UGRB ultimately attained the 2008 ozone NAAQS for a sixth-consecutive year in 2017.

2017: METEOROLOGY FACT SHEET

- ❄ 0.99 inches of total precipitation*** in January (319% of normal at Big Piney)
- ❄ 0.75 inches of total precipitation in February (214% of normal at Big Piney)
- ❄ 1.45 inches of total precipitation in March (329% of normal)
- ❄ -39 degrees Fahrenheit measured in January at Big Piney
- ❄ Five record-low temperatures set in January at Big Piney
- ❄ 12 Ozone Action Days issued for 2017 winter ozone season

***Note: Snowfall accumulation and total precipitation are two different measurements

THE DESIGN VALUE FOR THE 2017 WINTER OZONE SEASON

Even though the 2017 fourth-highest daily maximum of 73 ppb was higher than the 2015 ozone NAAQS of 70 ppb, the three-year average considers values of 55 ppb (2015) and 60 ppb (2016), generating a final design value input of 62 ppb. This design value calculation ensures that a potential outlier year of air quality is not the singular representation of a NAAQS classification.

TODAY'S PLANNING, TOMORROW'S RESULTS

It's been a long and winding journey, and we're not at our destination yet. The UGRB remains in nonattainment for the 2008 ozone NAAQS, and will continue to do so until it is formally redesignated to attainment by the EPA.

In order to submit a request for redesignation, the WDEQ must complete the five requirements of Clean Air Act Section 107(d)(3)(E).

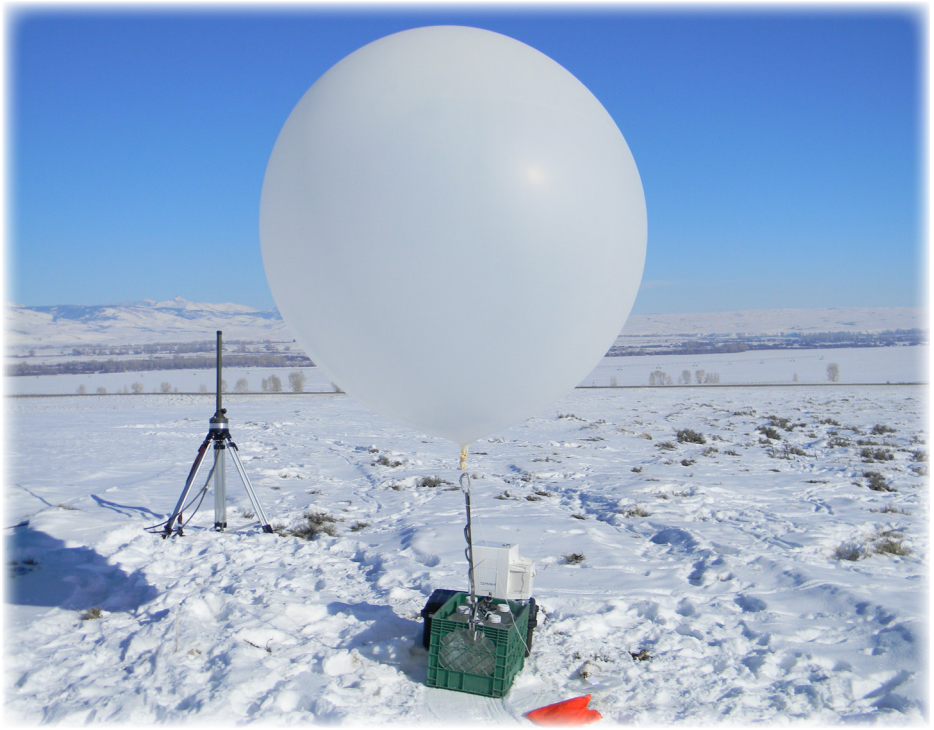
The first requirement (the EPA's Determination of Attainment) is completed, and we are continuing to evaluate our potential pathways forward. The WDEQ is familiar with the request for redesignation process, having successfully redesignated the City of Sheridan PM_{10} nonattainment area in April 2018. However, the process is lengthy.

Until then, we remain committed to seeing through the proactive teamwork that has paved the way to improved air quality conditions in the UGRB. After operators set all-time high participation levels in voluntary OCP submissions and implementing contingency measures on OADs in 2016, the 2017 season saw similar totals for activity in both categories.

We have held pre- and post-winter ozone season Open Houses in the UGRB for the last four years, providing the general public with a forum to interact with Division staff members, operators, environmental groups, and other stakeholders in the area. We've also undertaken and implemented an abundance of regulatory measures, policy directives, and voluntary emission reduction programs that have helped improve the air quality in the area.

We are proud of the work that has been accomplished, and even more proud of the collaboration that has gotten us there. Ensuring cleaner air for the citizens of the UGRB through proactive partnership remains an important initiative for WDEQ and the State of Wyoming – and we will continue to develop innovative and responsive approaches to accomplish this. It's the essence of how we're continuing to lead the way in the UGRB.

Together.



UGRB TECHNICAL WORK COMPENDIUM

This compendium details the technical work and studies undertaken in the UGRB with Division involvement between 2007 and 2017.

Upper Green Winter Ozone Study 2007:

✻ 2007 Monitoring and Quality Assurance Plan Upper Green River Winter Ozone Study. T&B Systems Inc., Meteorological Solutions Inc., Environ International Corporation, and Sonoma Technology Inc., prepared for Wyoming Department of Environmental Quality – Air Quality Division. August 2007.

✻ 2007 Upper Green River Winter Ozone Study. Environ International Corporation, T&B Systems Inc., and Meteorological Solutions Inc., prepared for the Wyoming Department of Environmental Quality – Air Quality Division. April 2008.

Winter 2007 to Present – Enhanced Winter Emissions Inventories:

✻ Collection of winter specific (February 1 – March 31) emissions inventories were initiated for the winter of 2007 as a result of growth in production and elevated wintertime ozone observations. The winter emissions inventories were expanded geographically in the winter of 2009 to the Upper Green River Basin (Sublette County and portions of Lincoln and Sweetwater Counties).

Southwest Wyoming Ambient Monitoring Network Assessment:

✻ Air Monitoring Network Assessment for Southwest Wyoming. Sonoma Technology, Inc., prepared for the Wyoming Department of Environmental Quality – Air Quality Division. August 2008.

Upper Green Winter Ozone Study 2008:

✻ Monitoring and Quality Assurance Plan for the Upper Green River Winter Ozone Study – 2008. T&B Systems Inc., Meteorological Solutions Inc., and Environ International Corporation, prepared for the Wyoming Department of Environmental Quality – Air Quality Division. February 2008.

✻ 2008 Upper Green River Winter Ozone Study. Environ International Corporation, T&B Systems Inc., and Meteorological Solutions Inc., prepared for the Wyoming Department of Environmental Quality – Air Quality Division. October 2008.

January 2009 & August 2011 – Technology Transfer:

✻ The AQD gathered industry and manufacturers together to share new technologies to reduce emissions.

Technical Support Documentation for Designation Recommendation:

✻ Technical Support Document I for Recommended 8-hour Ozone Designation for the Upper Green River Basin. State of Wyoming. March 2009.

CALMET Meteorological Modeling:

✻ Development of High-Resolution 3-Dimensional Wind Fields using CALMET (Phase I, February 18-24, 2008). TRC prepared for the Wyoming Department of Environmental Quality – Air Quality Division. May 2009.

✻ Upper Green River Winter Ozone Study: CALMET Database Development Phase II (February – March 2008). TRC, pre-

pared for Wyoming Department of Environmental Quality – Air Quality Division. August 2009.

December 2009 & September 2010 – Ozone Technical Forums:

✻ Ozone Technical Forums were meetings held by the AQD to bring together interested parties to share technical information about winter ozone formation and winter ozone modeling, as well as to hear from others in the professional community about what they knew about these matters. Ozone Technical Forum meetings were held by the AQD on an as-needed basis.

Upper Green River Ozone Investigation:

✻ Upper Green River Ozone Investigation (O3i). University of Wyoming Atmospheric Science Depart-ment, prepared for the Wyoming Department of Environmental Quality – Air Quality Division. December 2009.

✻ Upper Green River Ozone Investigation (O3i). Mobile Monitoring of Ozone Precursors – Big Piney, Luman Road, Boulder South Road, Pinedale and Olson Ranch Monitoring Sites. University of Wyoming Atmospheric Science Department, prepared for the Wyoming Department of Environmental Quality – Air Quality Division. January 2010.

✻ Upper Green River Ozone Investigation (O3i) Ozone Spatial Distribution Survey. University of Wyoming Atmospheric Science Department, prepared for the Wyoming Department of Environmental Quality – Air Quality Division. January 2010.

✻ Upper Green River Ozone Investigation (O3i) Luman and Paradise Road Traffic Count Study. University of Wyoming Atmospheric Science Department, prepared for the Wyoming Department of Environmental Quality – Air Quality Division. January 2010.

✻ Upper Green River Ozone Investigation (O3i) Olson Ranch Monitoring Site (2009-2010). University of Wyoming Atmospheric Science Department, prepared for the Wyoming Department of Environmental Quality – Air Quality Division. February 2010.

Winter Box Modeling:

✻ 2008 Winter Box Model Study. Environ International Corporation, prepared for the Wyoming Department of Environmental Quality – Air Quality Division. January 2010.

Conceptual Modeling:

✻ A conceptual model of winter ozone episodes in Southwest Wyoming. Environ International Corporation, prepared for the Wyoming Department of Environmental Quality – Air Quality Division. January 2010.

Upper Green Winter Ozone Study 2009:

✻ Monitoring and Quality Assurance Plan for the Upper Green River Winter Ozone Study – 2009. T&B Systems Inc., Meteorological Solutions Inc., and Environ International Corporation, prepared for the Wyoming Department of Environmental Quality – Air Quality Division. January 2009.

✻ 2009 Upper Green River Winter Ozone Study. Environ International Corporation, Meteorological Solutions Inc., T&B Systems Inc., and University of California Riverside, prepared for the Wyoming Department of Environmental Quality – Air Quality Division. March 2010.

Winter Box Modeling:

✻ Assessment of Winter Ozone in the Upper Green River Basin using the CALGRID Photochemical Grid Model. TRC, prepared for the Wyoming Department of Environmental Quality – Air Quality Division. April 2010.

Winter HONO Field Study:

✻ WDEQ UGWOS 2010 HONO Measurements. B. Rappenglük, report to Meteorological Solutions Inc., prepared for the Wyoming Department of Environmental Quality – Air Quality Division. May 2010.

Grid Modeling:

✻ Summary of Comparison between Canister Data and CALGRID Model Output for the February 18-24 period. TRC, prepared for the Wyoming Department of Environmental Quality – Air Quality Division. April 2010.

✻ Summary Report for the assessment of winter ozone in the Upper Green River Basin using the CALGRID Photochemical Grid Model for the February 18-

24, 2008 Period. TRC, prepared for the Wyoming Department of Environmental Quality – Air Quality Division. June 2010.

Transport Assessment:

✻ An Air Parcel Transport Corridor Analysis for Sublette County, Wyoming. Sonoma Technology, Inc., prepared for the Wyoming Department of Environmental Quality – Air Quality Division and presented to the Sublette County Commission. September 2010.

Upper Green Winter Ozone Study 2010:

✻ Monitoring and Quality Assurance Plan for the Upper Green River Winter Ozone Study – 2010. Meteorological Solutions, Inc., T&B Systems Inc., and Environ International Corporation, prepared for the Wyoming Department of Environmental Quality – Air Quality Division. February 2010.

✻ 2010 Upper Green River Ozone Study. Meteorological Solutions Inc., Environ International Corporation, and T&B Systems Inc., prepared for the Wyoming Department of Environmental Quality – Air Quality Division. December 2010.

Screening Health Risk Assessment, Sublette County, WY:

✻ Sublette County Air Toxics Inhalation Project – Final Data Submittal Report, February 3, 2009 – March 31, 2010. Air Resource Specialists, Inc., prepared for the Sublette County Commissioners, the Wyoming Department of Environmental Quality, and the Wyoming Department of Health. June 2010.

✻ Screening Health Risk Assessment, Sublette County, Wyoming. Sierra Research, Inc., prepared for the Sublette County Commissioners, the Wyoming Department of Environmental Quality, and the Wyoming Department of Health. January 2011.

2010-2011: Technical Advisory Group:

✻ The AQD established a Technical Advisory Group (TAG) consisting of AQD personnel, academics, industry representatives, consultants, and other interested parties. The TAG provided technical feedback on air quality modeling. While the TAG focused on modeling issues, additional emissions and monitoring knowledge as it relates to modeling were beneficial. The TAG acted in an advisory capacity to the AQD and also provided advice to the AQD on potential path(s) forward. The AQD maintained sole decision-making authority.

VOC Reactivity/Modeling Studies:

✻ Estimation of VOC Incremental Reactivities in Winter Ozone Episodes in the Upper Green River Basin of Western Wyoming. W.P.L. Carter and J.H. Seinfeld, prepared for the Wyoming Department of Environmental Quality – Air Quality Division. June 2011.

Upper Green Winter Ozone Study 2011:

✻ Monitoring and Quality Assurance Plan for the Upper Green River Winter Ozone Study – 2011. Meteorological Solutions Inc., T&B Systems Inc., and Environ International Corporation, prepared for the Wyoming Department of Environmental Quality – Air Quality Division. February 2011.

✻ 2011 Upper Green River Ozone Study. Meteorological Solutions, Inc., Environ International Corporation, and T&B Systems Inc., prepared for the Wyoming Department of Environmental Quality – Air Quality Division. October 2011.

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